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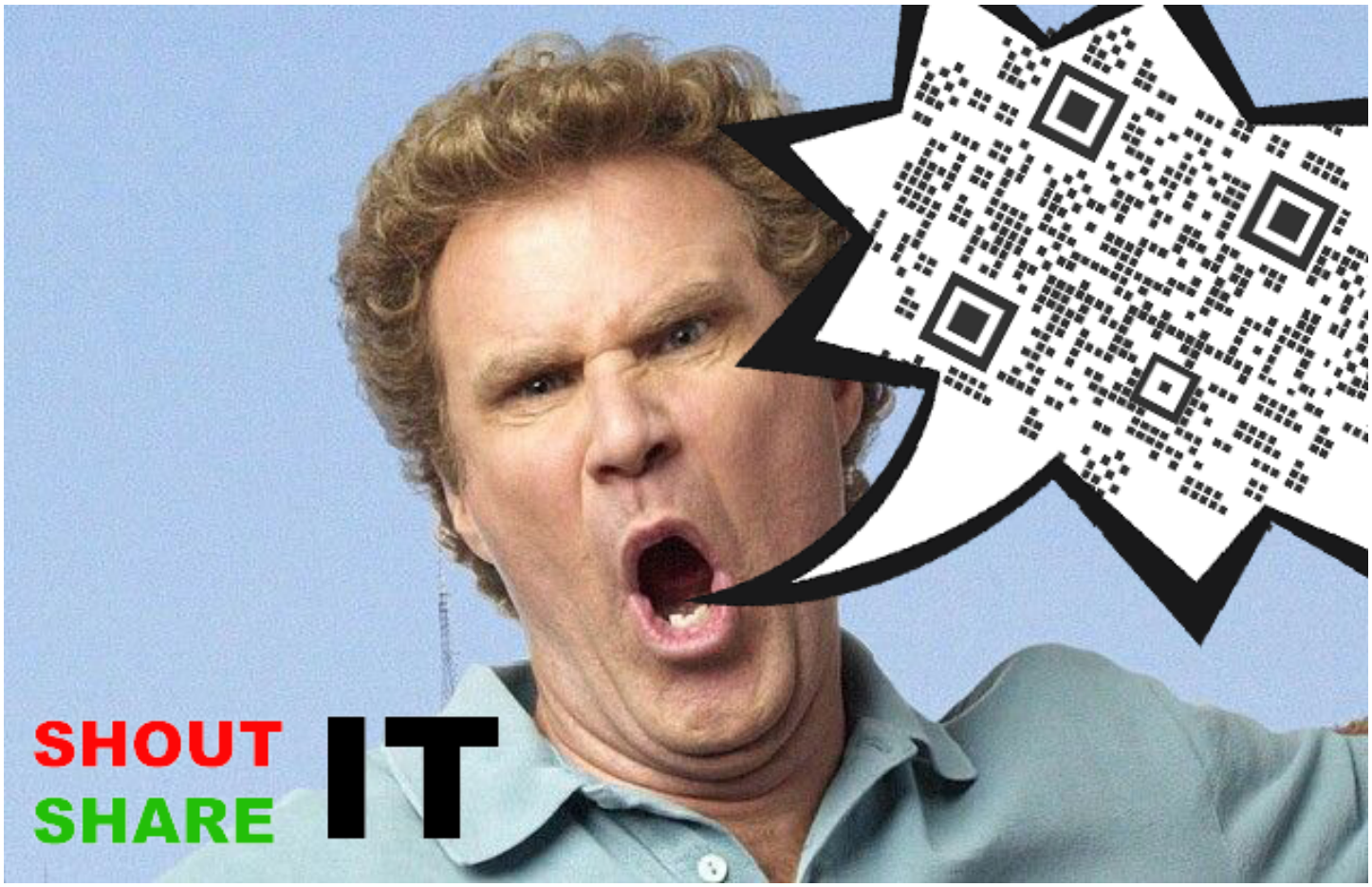
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STRAINS OF WHITE BURLEY TOBACCO RESISTANT TO ROOT-ROT.

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RELATION OF ROOT-ROT TO THE CROPPING SYSTEM IN PRACTICAL TOBACCO CULTURE.

In the systems of tobacco culture prevailing in the United States there are two outstanding extremes in the management of the land. In one case tobacco is grown on the same soil year after year for indefinite periods, while in the other there is a rotation of crops in which only one or two crops of tobacco are grown on the land in a period of 8 to 10 years. The continuous-culture system is characteristic of the cigar-tobacco section of New England and to a considerable extent of Wisconsin and Ohio, while on the tobacco lands of Pennsylvania the systematic rotation of crops is the rule. In the southern tobacco-growing sections generally there is considerable variation in farm practice in this particular, but in most districts it is seldom that the system of continuous tobacco culture is attempted. The practice of growing only one or two crops of tobacco on the land and then allowing a period of 6 to 10 years to elapse before cropping to tobacco again is especially characteristic of the Burley section of Kentucky and the adjoining States.

These radically different practices have not developed without good reason on the part of the growers, and the cause is a matter

which will be briefly considered at this time. In the Connecticut Valley tobacco growers have less area to exploit, and although the land is not naturally fertile heavy applications of commercial fertilizers are used with profit. Under the conditions there experience has shown that it is possible to grow tobacco commercially with more or less success by the continuous-culture system. In the Burley district there is as a rule no dearth of tobacco land and the soil is naturally quite fertile, so that practically no commercial fertilizers are used. Here experience has shown that tobacco can not be successfully grown on the same soil for more than two years in succession, although other crops following tobacco will grow very satisfactorily. Briefly, the accepted explanation for half a century has been that tobacco is very hard on the soil, in that it removes great quantities of plant food, and some growers have thought that the supply of certain kinds of this food which are essential for tobacco but not for other crops becomes exhausted, at least temporarily. In Connecticut, then, enormous applications of fertilizer have been resorted to in order to maintain production, while in the Burley district the soil which has grown tobacco for one or two years is given a 5 to 10 year "rest," usually in sod, to remedy the condition of "exhaustion."

The purpose of this bulletin is to show the incorrectness of the commonly accepted explanations, especially as applied to the Burley section. The cigar-tobacco sections have made equally incorrect interpretations of the special requirements of the tobacco crop, and the attempt has been made to maintain production by heavy applications of fertilizer rather than by crop rotation. Owing to the variety of tobacco grown, it will be shown that the Burley grower is at once forced to change his land, whereas, on the other hand, the cigar-tobacco grower, using other varieties, has been able to keep up continuous cropping with considerable success. It is now known that there is a root disease which has been an important factor in determining cropping methods used in tobacco culture.

DESCRIPTION OF ROOT-ROT.

In some sections many tobacco growers have become more or less acquainted with the disease of tobacco known as root-rot and realize its importance as related to crop production. Unfortunately, however, a great many growers are entirely unaware of the occurrence of the disease, even though it be the cause of a total failure of the tobacco crop on their soils. The primary reason for this is at once evident. Though growers as a rule are very keen in observing small diseased areas on the stems and leaves of plants, they rarely examine with care the roots, which are hidden in the soil. Many growers gain their first acquaintance with the root-rot while pulling plants from the seed beds. In some districts most tobacco growers, per-

haps, have noticed in certain years or on some plants roots which are not only small in size and number but which are decayed and brown or black, instead of having normally abundant roots of pure-white color. No great attention is given to this, since it is known that such plants when set in the field send out new roots and may appear to start out almost as well as healthy plants. Nevertheless, this condition is frequently the source of future difficulties. The plants may or may not recover from this trouble, depending on a number of environmental factors. Fortunately, plants so affected often do not make a sufficiently vigorous growth in the beds to permit transplanting; hence they save some discouragement later. In passing, then, it may be said that the root disease is one of the common causes of plants turning yellow and failing to grow properly in the beds.

It has been found that the amount of damage done by the root disease is largely dependent upon the temperature of the soil, which is, of course, controlled largely by the temperature of the air. Low temperatures (60° to 75° F.) favor root-rot, while high soil temperatures (80° to 100° F.) practically prevent the disease from developing. Therefore, if the season is relatively warm, diseased plants may partially or wholly recover. However, all growing seasons have periods, sometimes extending over most of the season, when the weather is cool. Recovery then does not occur or is very slow. The plants refuse to grow, or make little headway as compared with neighboring fields on ground free from disease, and the crop prospects are much reduced. Frequently, however, after long cool periods a week or two of very warm weather starts the crop into a very rapid growth if sufficient moisture is present or if plenty of rainfall occurs.

A common occurrence, even in the Burley district, where a rotation system is practiced, is the transplanting of healthy (or diseased) plants into soils which already harbor the root trouble. These soils we will hereafter call "sick" soils. The result so far as crop production is concerned will depend largely on seasonal conditions, especially as to soil temperature, as previously described. A crop may or may not be produced. The situation as a whole, however, is much more serious, since this is by far the most common way in which the disease starts, and all the plants become involved. For all practical purposes it is safe to say that in the Burley district substantially all fields which have grown two or more crops of tobacco (and often those growing only one crop) are more or less "tobacco sick." This disease does not attack grains, corn, or hemp, and, in fact, affects no other agricultural crop except certain legumes, these sick tobacco soils being capable of growing such crops in a satisfactory manner so far as root-rot is concerned.

The symptom of this disease is, then, a decay of the root system, resulting in a stunting of the plants, roughly proportional to the extent of the decay in the roots. The effect of the disease on the root system and the growth of the plant is shown in figure 1. Very frequently the plants make no growth during the season, on account of this disease. Curiously enough, root-rot rarely kills the plants in the field. Aside from becoming stunted and yellow, they may show wilt-

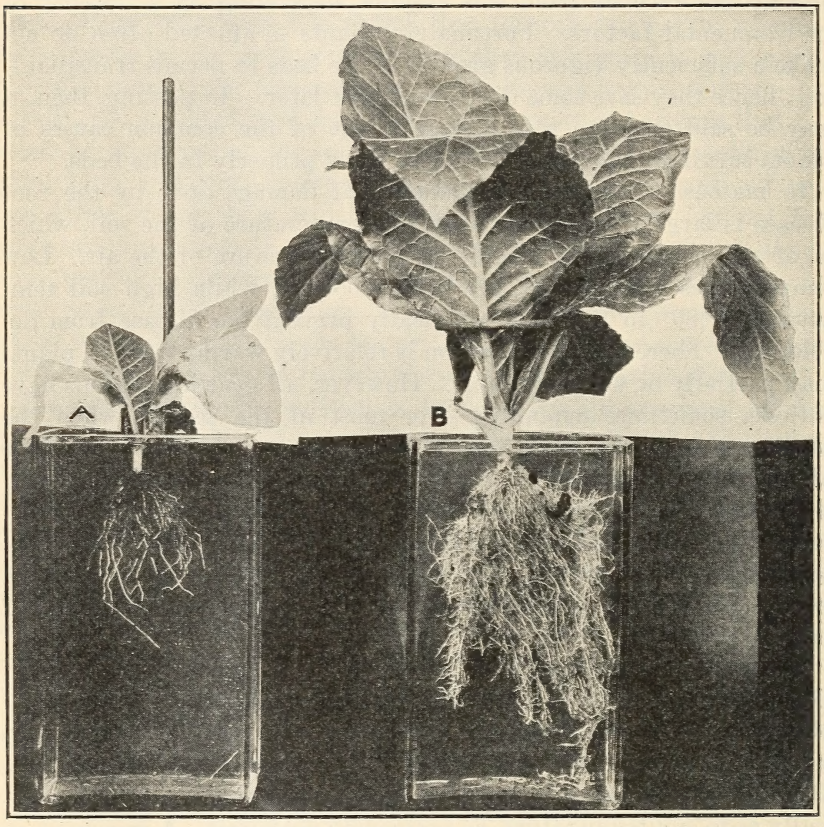

FIG. 1.—Plants of Burley tobacco grown on "tobacco-sick" soil (*A*) and in soil free from disease (*B*), showing the relative number of roots. These plants were grown under identical conditions, except that the soil in which plant *B* was grown was sterilized, so as to kill the parasites causing the disease.

ing, even in very moist soils, on days when tobacco in healthy soil and other crops show no wilting. The depleted root system is not able to take up water as fast as the leaves lose it, causing temporary wilting. It is not, however, a typical wilt disease, since the leaves do not remain wilted. Crops with root-rot suffer from "drought," therefore, very much more quickly than healthy crops.

The importance of this disease is shown by the fact that careful observations over a considerable part of the tobacco-growing sections

of the United States in recent years have shown that the damage annually runs into millions of dollars. The loss in Kentucky alone must easily exceed on the average $2,000,000 yearly.

CAUSE OF THE DISEASE.

The root-rot is caused by a fungus which lives as a parasite on the roots of the plant. This organism, or germ, although so small that it can not be seen except with a high-power miscroscope, is still a very large organism as compared with other parasites which produce well-known diseases in plants and animals. This organism is called *Thielavia basicola*, and technically this disease should be called the Thielavia root-rot, since there are many other organisms which cause root diseases in other plants. This fungus can grow into the roots of the tobacco plant and feed on its tissues, which results in their decay. Moreover, it can live on dead organic material in the soil, though not as readily, and in the absence of the tobacco plant from the soil it gradually dies out, though this may require from 5 to 10 years or more. The exact time has not yet been determined, but it probably varies somewhat with different types of soil. The disease spreads very much in the same way as other diseases of plants and animals. It is sometimes very difficult to account for the first infection by the fungus. The most common means of spreading it is through the transference of sick soil, either by wind, water, or animals, to healthy soil or by the transplanting of diseased plants from infested seed beds.

With this description of the nature and cause of the disease, the skeptical grower has still the right to ask for proof that the root-rot is doing the amount of damage claimed and that it, and not depletion of soil fertility, is the reason why tobacco soils in the Burley section require several years of "rest" after having grown one, two, or three crops of tobacco. There exists, fortunately, a convenient and convincing proof of this fact. This lies in varietal differences in resistance and susceptibility to the disease.

VARIETAL RESISTANCE AND SUSCEPTIBILITY.

It is now a well-established fact that plants as well as animals differ in their degree of susceptibility to disease. This is now known to hold true for the tobacco plant as regards the Thielavia root-rot.

If two varieties of tobacco, Connecticut Havana and White Burley, for instance, are planted side by side on ground which has just grown two or three crops of Burley, the Havana seed in most instances will produce at the end of the season from two to a hundred times as much weight as the Burley. If, however, these two varieties are planted on ground on which tobacco has not been grown for

several years and which is not "tobacco sick," the Burley tobacco will produce as great or a greater weight, plant for plant or acre for acre, than the Connecticut Havana. If we pull up and examine the roots of plants of both varieties grown on healthy ground, they are found to be large and white. On sick soil, however, a Burley plant will usually have only relatively few stubby black roots, as compared with the Havana tobacco, although the latter variety also may show some signs of the disease. The difference in yields between two varieties can be made even more striking, since we have varieties two and three times as resistant as the Connecticut Havana. No variety more susceptible than the ordinary White Burley strains grown in the Burley section has been found. Such a test can be made easily on any soil, and in connection with this study it has been repeated a great many times, with the expected results in nearly every instance. Where the expectations were not realized there has been good reason for suspecting disturbing factors other than the Thielavia root-rot.

The behavior of resistant and susceptible varieties on sick soils is regarded as positive proof of the extent of the injury attributed to the root-rot. It can be satisfactorily explained in no other way. The accumulation of data upon the subject over a period of five years in Wisconsin, Connecticut, Kentucky, and in Canada, together with field surveys in other States, has left no doubt of the widespread occurrence and economic importance of the disease.

With the marked differences in resistance to the root-rot manifested by different varieties of tobacco clearly in mind, it will be readily seen that these differences satisfactorily account for the marked contrast in methods of handling tobacco lands in some of the northern cigar-tobacco districts and in the Burley district. The extreme susceptibility of the Burley variety permits of no other system than a short cropping period for tobacco and a long "rest" for the land. In the northern cigar-tobacco districts tobacco culture has involved a struggle between old sick soils and the resistance of the varieties grown. The influence of this struggle upon agricultural practice has been threefold. First, the growers have applied enormous quantities of fertilizers, hoping thereby to remedy the worn-out condition of the soils, which has resulted in more or less wastage of fertility, since sick soils can not be benefited appreciably by fertilizers except under special conditions (by the use of resistant types, through prevailing high soil temperatures, etc.). In the second place, resistant strains apparently have been unknowingly selected and developed on account of their adaptability to these soils. In the third place, the disease in many instances has made such progress that growers have been compelled to change to new soils frequently, and

in some northern districts tobacco has been given a definite and permanent place in rotation with other farm crops.

DEVELOPMENT OF BURLEY STRAINS RESISTANT TO ROOT-ROT.

Although a high measure of control of the root-rot in the Burley section is attained by the system of rotation in use it is evident that, on account of the extreme susceptibility of the Burley variety, considerable disease occurs annually. The susceptibility of this variety not only prevents continued culture when desired, but also makes the growing of second and third crops on the soil quite a game of chance. A type of Burley as resistant as some of the cigar varieties and still possessing the yield and quality of the ordinary Burley strains therefore would be extremely valuable in reducing the annual loss from disease. Two possible means of producing such a type are selection for disease resistance among commercial varieties now grown and crossing resistant green types, such as some of the cigar tobaccos, with White Burley, for the purpose of adding disease resistance to the White Burley characteristics. The first method, that is, selection for resistant strains in diseased fields, has been resorted to in obtaining the results presented here. All tobacco growers have seen fields in which the crop has made a very uneven growth, though all the plants apparently had an equal chance to start and develop. It sometimes happens that these fields behave in this manner because of the presence of the root-rot and the use of impure seed. Those plants which grow rapidly and stand out distinctly from their neighbors may be resistant to the disease. A large number of these have been selected and the seeds saved from the individual plants and grown in separate rows on sick soils the following year. A few of these selections have shown very distinct resistance when compared with ordinary Burley, and these strains propagated and tested over a period of several years under many varied conditions have continued to maintain their original degree of resistance. In some cases these strains have been tested on a rather large scale on both healthy and sick soils for the purpose of comparing the quality of the cured leaf produced with that of the ordinary White Burley. The results on the whole have been very encouraging, although the ideal in mind has not yet been reached. The resistant strains thus far produced and given commercial trial are all of the drooping-leaf type and not stand-up Burleys, which many growers prefer. Encouraging results have now been secured in developing resistance in the stand-up types also, and it is expected that these strains will soon be ready for testing commercially.

A more important feature, however, is the quality of the resistant Burleys obtained, as compared with the best strains of ordinary

Burley. Quality in Burley tobacco is largely a matter of the color and texture of the cured product. Several trials have shown that the resistant type is practically equal to the ordinary Burley varieties in these respects. The final criterion must be the relative prices brought on the warehouse floor. In this, the resistant Burley has so far shown itself to be equally as valuable as the ordinary Burleys. In the field, however, it seems that the top leaves do not color up as rapidly or as brightly as some of the best strains of ordinary Burley. The importance of this from a commercial standpoint is seemingly not great, although it is true that it may result in somewhat more "red leaf." The fact that the resistant Burley makes a more vigorous growth on partially sick soils, however, will generally result in a greater proportion of the higher priced grades, which, together with a larger total yield, may fully offset any disadvantage of slightly reduced color. Briefly stated, some of the best strains of the ordinary Burley may produce better quality on healthy soil, but on sick soil the resistant Burley will usually prove better in both yield and quality.

The results attained up to the present time warrant the recommendation of the resistant type for growing on all sick soils in the Burley section on which it is to be expected that the ordinary varieties of White Burley will give unsatisfactory yields. It is hoped that in the near future the resistant character will be introduced into the best strains of ordinary Burley, so that they may be grown successfully on diseased as well as on healthy soils.

EXPERIMENTS IN THE WHITE BURLEY DISTRICT OF KENTUCKY.

The resistant Burley strains have been tested on several farms in the Burley section of Kentucky during the past three years. These demonstrations have been made on the farms of Mr. E. F. Shropshire, Lexington; Dr. S. H. Halley, Paynes Depot; Mr. William Feck, Lexington; Mr. N. H. Witherspoon, Winchester; and Mr. J. Waller Rodes, Lexington. Several others also have grown some of the strains on trial. The progress of the work from the standpoint of the demonstration of disease resistance has been hampered somewhat by the difficulty of finding growers who were willing to put in third or fourth crops in succession on the same soil, since it was felt that a crop failure with Burley would be almost certain to follow. Such soils, however, have been obtained in a few instances. On the farm of Mr. E. F. Shropshire, Maysville Pike, Lexington, a plat which had already grown three crops of Burley was secured in 1916. Resistant and ordinary Burleys have been planted on this land for the last three years. The results each season have been striking. The ordinary Burleys have made practically no growth, while the re-

sistant strains have made on the average a normal growth each year. This land, therefore, has been made to produce six crops in succession by the use of the resistant Burley variety. The comparative

FIG. 2.—Resistant White Burley and ordinary White Burley strains of tobacco grown on "sick" soil in alternate rows. The rows of ordinary Burley have made almost no growth since transplanting. Farm of E. F. Shropshire, Lexington, Ky., 1916.

growth of these resistant strains and the ordinary types of Burley is shown in figures 2 and 3. In northern tobacco districts, where old tobacco soils are more easily obtainable for such tests, fair crops of

FIG. 3.—Resistant White Burley and ordinary White Burley strains of tobacco grown on "sick" soil on the farm of E. F. Shropshire, Lexington, Ky., in 1917, showing the relative growth early in the season.

resistant Burley have been grown after 12 successive crops of tobacco. Results similar to those secured at the Shropshire farm have been obtained at several other places, indicating the general occurrence of

sick land and the adaptability of resistant Burley to it. The behavior of the resistant strains as compared with the ordinary Burleys on the farm of Mr. William Feck is shown in figure 4. It does not follow, nor is it recommended, that continuous culture of Burley tobacco should be practiced in the Burley section. On small farms or where suitable soil is scarce it may be highly desirable to grow tobacco on the same land more frequently than hitherto has been possible. The important point, however, is that the number of tobacco crops which may be grown on a given piece of land usually is not sharply limited by lack of fertility, but rather by disease. The value of resistant strains, therefore, lies in reducing the chances of poor yields in second or third crops on soils gradually becoming sick.

FIG. 4.—Resistant White Burley tobacco (on the right) and ordinary White Burley strains (on the left) growing on the farm of William Feck, Lexington, Ky., in 1917. The tobacco was about half grown when the photograph was taken.

With respect to the quality of the resistant Burley, considerable evidence is at hand to show that so far as market value is concerned it has not proved to be inferior to the ordinary strains. Some of the growers who tried this seed in 1917 on a small scale planted as many as 10 or 15 acres in 1918. The final reports as to the quality of the 1918 crop are not yet obtainable, but there is no reason to believe that its average value will be less than that of ordinary Burley, i. e., the Kelly, Halley, Big Stand-up, and other strains.

RESISTANT BURLEY STRAINS RECOMMENDED FOR SICK SOILS IN WHITE BURLEY DISTRICTS.

Until stand-up Burleys of unquestionable perfection in quality are obtained it is believed that growers can very profitably plant the resistant drooping-leaved variety of Burley where it is desired to utilize sick soils. It is recommended that those who are putting in second

or third crops of Burley or have reason to suspect that the root-rot is present try some of the resistant Burley seed. The grower will thus have an opportunity to determine to his own satisfaction the cause of tobacco-sick soil and at the same time to compare the type and quality of the resistant Burley with that of the ordinary strains. For a proper test it is necessary, of course, that some ordinary Burley be grown on the diseased soil alongside of the resistant strains and handled in the same way in all respects, for otherwise there will be no accurate basis for comparison. Two or three strains of the resistant Burley seed are available for distribution, and although one strain may be slightly better than another, few or no data on this point have yet been obtained. Where the land has had a long rest from tobacco the resistant type is not recommended, for it will not show any improvement over ordinary Burley on healthy soil. The value of these new strains lies in their resistance to root-rot; hence, there would be no purpose in growing them on land free from this disease except in so far as they reduce the injury from root-rot due to the transplanting of diseased plants from infested seed beds.

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